Tobacco Moisture Content Determination by Microwave Heating

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ABSTRACT

SAMPLES of shredded burley tobacco leaves were heated for a fixed time interval in a microwave oven and the resulting temperature rise was correlated to the sample moisture content. The results showed that the moisture content of tobacco leaves, from 9 to 23 % wb, is a function of temperature rise when 50 g samples are heated for 18 s at maximum power of 625 W in a home microwave oven. The accuracy is improved with shredded samples by reducing the uneven heating that occurs with whole leaf samples, lowering the standard error for the prediction equation from 1.04 % wb to 0.68 % wb. Much of the remaining uneven heating is due to the inadequacy of the microwave applicator.

INTRODUCTION

Whenever burley tobacco is to be stored by farmers, the moisture content must be known to determine if it must be dried to avoid spoilage. Tobacco processors must know the tobacco's moisture content to estimate the drying time. When burley tobacco is sold, its moisture content is not considered unless it is judged to be so moist that it is in danger of spoilage. This system encourages farmers to keep and sell their tobacco at as high a moisture content as possible, which endangers the quality of burley tobacco being sold. Such a practice of selling high moisture tobacco in turn endangers the market for the tobacco since burley tobacco's strongest attribute in the past has been its high quality.

At present there is no standard for moisture content determination of tobacco. The oven drying techniques that are usually employed are much slower than is desirable, especially if moisture content were being determined at the point of sale. Many researchers have modified oven drying methods for grain by using microwave ovens to drive off moisture much faster than is possible with an air oven (Click and Baker, 1980; Farmer and Brusewitz, 1980; and Verma et al., 1983). Gorakhpurwalla et al. (1975) tested an experimental microwave applicator and dried grain for moisture content determination. Okabe et al. (1973) effectively determined moisture content of rice and wheat by measuring the microwave attenuation as a function of grain type and moisture content.

Casada et al. (1983) correlated the temperature rise of whole burley tobacco leaves to moisture content when the leaves were subjected to microwave radiation for a fixed time interval. This method predicted the moisture content to ±2.1% wb with a 95% confidence level. The nonhomogeneous nature of whole tobacco leaves was thought to cause much of the uneven heating that reduced the accuracy of moisture content determinations. The research described in this paper will continue the work of Casada et al. (1983) by studying the effect of shredding the tobacco leaves before testing.

Using samples of shredded tobacco should minimize uneven heating that is a result of the nonhomogeneous samples and, thus, improve the accuracy of moisture content determination by microwave heating. The objectives of this research were: (a) to find the moisture content of shredded burley tobacco as a function of temperature rise under microwave radiation, and (b) to determine how much the accuracy of such moisture content determinations is improved by reducing the uneven heating that occurs with whole leaves.

METHODS

Shredded tobacco (13 cuts/cm) from leaves at the middle stalk position at 26% wb moisture content was divided into six lots. Each lot was dried to a different moisture content resulting in moisture levels of approximately 9, 11, 13.5, 16, 19, and 23% wb. The 50 g samples, which were placed in a rectangular plastic container approximately 11.4 cm × 12.7 cm × 3.2 cm with 5 cm of polystyrene foam insulation on all sides, filled the container to approximately 2.5 cm depth. Each sample was irradiated at maximum power of 625W* for 18s. The heating time of 18s was used because this time had been shown by Casada et al. (1983) to give acceptable temperature rise without driving off significant amounts of moisture. The samples were rotated continuously while in the oven with a typical commercially available dish rotator for home microwave ovens. After removing the sample from the oven, nine thermocouples were inserted through holes in the top of the insulation within one minute after cessation of radiation, and the tobacco temperatures recorded for 18 min, using a digital thermometer with 0.56 °C (1 °F) resolution. The temperatures were initially read every 30 s, with the time between readings gradually increased to 3 min as the rate of cooling decreased. These nine temperatures were used to find the sample's average temperature rise at any given time.

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*All test were conducted in a Sears Kenmore Microwave Oven model 99601 rated by the manufacturer as 625W at 2450 MHz. Use of tradenames does not imply endorsement of the product by the authors or by the Kentucky Experimental Station.

Three separate samples (trials) of 50 g each were randomly selected from the same lot, and the results averaged for each test. Three replications of these tests were run at each moisture level. The actual moisture content of each sample was determined by air oven drying at 70 °C for 72 h. This test procedure was identical to the tests on whole burley leaves except that the sample holder was not inverted with shredded tobacco to reduce convective heat loss from the thermocouple holes.

Actual moisture contents were plotted as a function of temperature rise at the various time intervals after radiation ceased. Least-squares best fit parabolic equations were fit to these data. The accuracy of the moisture content prediction curves was evaluated by the standard error of regression, defined as

$$S.E. = \sqrt{\frac{\sum_{i=1}^{n} (Y_i - Y_p)^2}{n - 1}}$$

where, S.E. = standard error of regression,
Y_i = actual moisture content, and
Y_p = predicted moisture content, and
n = number of observations.

RESULTS AND DISCUSSION

The standard errors of regression for the parabolic equations used to predict moisture content for the shredded tobacco and the standard errors for whole leaves (Casada et al., 1983) are shown in Fig. 1 as a function of time after radiation stopped. The standard error for shredded tobacco improved with time for the first four minutes, as the hot and cool spots in the samples equilibrated, and then increased slowly for the rest of time. These standard errors were much lower than those for whole tobacco leaves, and also quickly reached a minimum value, whereas, the whole leaf standard errors were still decreasing at least ten minutes after radiation stopped. This indicates that there was more even heating in the shredded samples, which would reduce the scatter in the results, along with faster equilibration of any hot spots which did exist. The coefficient of variation (standard deviation divided by the mean) associated with the average of the temperature rises of the three replications of each test was calculated at the different times after radiation stopped, for both the whole leaf and shredded samples. The coefficients of variation were lower for the shredded tobacco. This improvement reached a maximum of 16% difference at two minutes after radiation stopped.

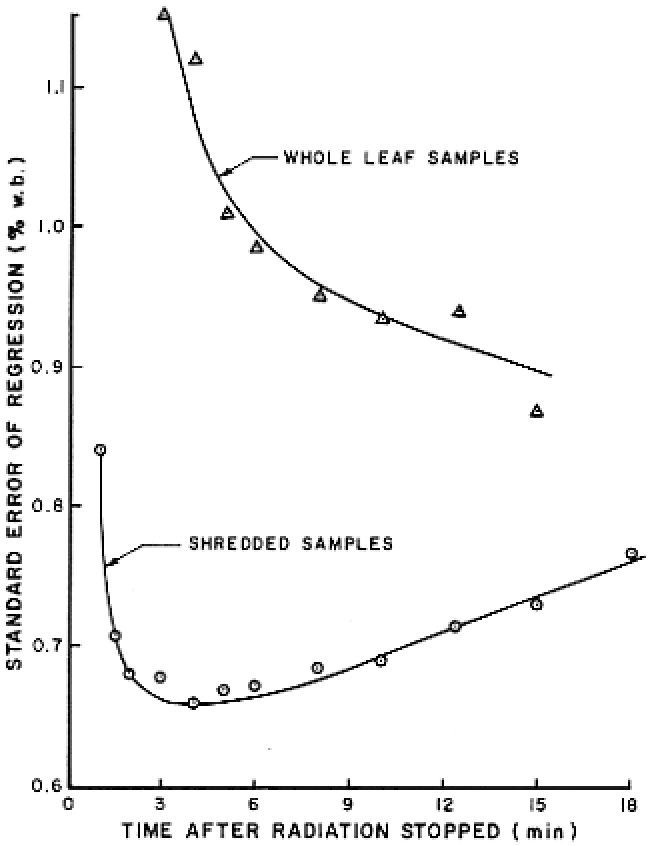

Fig. 1—Standard error of regression for whole leaf and shredded samples as a function of time after cessation of radiation.

TABLE 1. DEGREES OF TEMPERATURE RISE PER PERCENT MOISTURE CONTENT OVER A RANGE OF MOISTURE CONTENTS AND TIMES AFTER CESSATION OF RADIATION.

Time	Temperature rise per percent moisture content, °C/% wb				
	Moisture content, % wb				
min	9.0	12.5	16	19.5	23
1.0	5.55	2.33	1.72	1.43	1.25
1.5	4.45	2.15	1.52	1.35	1.18
2.0	3.69	2.04	1.56	1.32	1.16
3.0	3.23	1.35	1.49	1.26	1.11
4.0	2.95	1.82	1.43	1.22	1.08
5.0	2.84	1.76	1.38	1.18	1.04
6.0	1.85	1.73	1.35	1.15	1.01
8.0	2.88	1.65	1.28	1.08	0.95
10.0	2.75	1.58	1.22	1.04	0.91
12.5	2.60	1.51	1.16	0.98	0.86
15.0	2.52	1.44	1.11	0.94	0.83
18.0	2.44	1.37	1.06	0.89	0.78

The degrees of temperature rise per percent moisture content, which indicates how well the technique distinguishes between different moisture contents, is shown in Table 1 to decrease with time after radiation stopped. At two minutes after the radiation ceased it was still 1.16°C/% wb for the worst case, 23% wb. Each of the nine temperatures in the sample had a precision of ±0.3 °C. If it is assumed that the error in the sample average temperature was only ±0.3°C, the error in the moisture content given by the prediction equation in Fig. 2 would be 0.26% wb, which is still well within the range

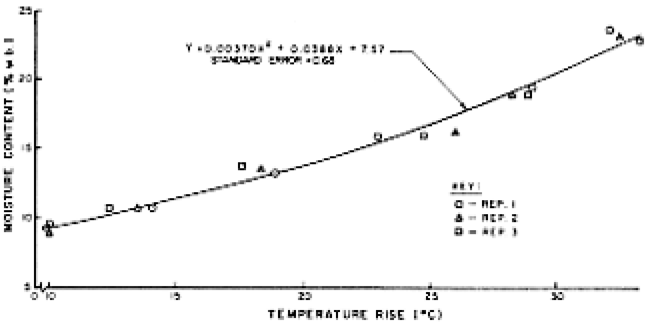

Fig. 2—A parabolic equation used to describe moisture content of shredded samples as a function of temperature rise under microwave radiation at two minutes after cessation of radiation.

of the 95% confidence interval of ±1.36% wb on the prediction equation in Fig. 2. The temperature rise per percent moisture content was even higher at all moisture contents less than 23% wb as is shown in Table 1.

The slight improvement in the standard error at four minutes, as compared to two minutes, was judged as not sufficient to warrant doubling the length of the tests; therefore, based on the standard error of regression being nearly minimum at two minutes and the temperature rise per percent moisture content still being acceptable at two minutes, this was the time selected for moisture content prediction. The prediction curve at two minutes is shown in Fig. 2. The parabolic equation used to predict moisture content had a standard error of 0.68% wb, which was 35% lower than the standard error of 1.04% wb for whole tobacco leaves (Casada et al., 1983).

This improvement in the accuracy of the moisture content prediction was twice as large as the 16% improvement in the uniformity of heating, as indicated by the coefficient of variation for the average temperature. This additional improvement was apparently because the improvement in the uniformity of heating allowed a more accurate measurement of the true average temperature, in addition to the improvement in the uniformity of heating itself. Also, the varying geometry of the folded leaves in the whole leaf samples may have caused variations in the total heating from sample to sample, which did not occur in the homogeneous shredded samples. Much of the remaining uneven heating can be attributed to the properties of the microwave oven (Casada et al., 1983).

This method of moisture content determination is accurate enough to be quite useful, especially when the tobacco is already in a shredded form, which is often the case for tobacco processors; however, when whole leaves must be shredded immediately before testing, error might be introduced by a change in moisture content while shredding. This drawback would be avoided if whole leaf samples were tested directly, but the accuracy would be reduced (Casada et al., 1983).

CONCLUSIONS

The following conclusions were formulated from the results of this research:

1. The moisture content of shredded burley tobacco, in the range of 9 to 23% wb, was a parabolic function of temperature rise under microwave radiation, with a standard error of regression of 0.68% wb for 18 observations.

2. The more uniform heating as well as other improvements from shredding the tobacco improved the accuracy of moisture content determination by 35% as compared to whole leaf samples.

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